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Superfluid transition and solidification of ^{4}He in aerogel

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Abstract

Superfluid transition and solidification of ^{4}He in aerogel has been studied by longitudinal ultrasound. The superfluid transition temperature was determined up to the solidification pressure. The superfluid transition temperature in aerogel which was identified as a sharp absorption peak was suppressed from that in bulk liquid. The magnitude of suppression in aerogel was a few milli-Kelvin from the saturated vapor pressure to the solidification pressure and was much smaller than that in other porous media. The onset of solidification of ^{4}He in aerogel was identified as an increase in sound absorption. It was shown that the overpressure required to initiate solidification was 0.2–0.3 MPa between 1.1 and 1.8 K. Small hysteresis was observed at the solidification and melting.

Keywords: B. Crystal growth; C. Ultrasonic measurements; D. Acoustical properties; D. Phonons; D. Phase transitions

1. Introduction

Porous media filled with ^{4}He have been intensively studied experimentally and theoretically. Recent experiments on the superfluid transition of ^{4}He contained in porous media such as Aerogel, Xerogel and Vycor glass have revealed that the superfluid transition differs from that of bulk ^{4}He [1,2].

A number of works done to study ^{4}He properties at elevated pressures [3–5] showed that the pressure–temperature (P–T) phase diagram is significantly altered for helium in porous material. For example, ^{4}He has been found to remain a liquid at pressures higher than bulk freezing (in Vycor glass -up to 4.2 MPa [3]). Recently it was reported in [6] about possible observation of a supersolid helium phase in Vycor from torsional oscillator measurements. In ^{4}He in Vycor, several sound experiments have been done [7,8]. The experimental results in the liquid phase have been elucidated by the Biot model [9].

Silica aerogels are synthesized via a sol-gel process and hypercritical drying which enable aerogel to have porosity as large as 99.8%. In the case of ^{4}He confined in a rigid medium with sufficiently small pores like Vycor, the normal fluid is viscously locked to the substrate. So only superfluid is free to move and supports pressure waves (the fourth sound). In aerogels (so-called highly compliant media) the normal fluid, though locked to the substrate, drags the substrate along and one can observe two propagating sound modes [10,11]. As far as in this case the substrate adds both its mass and a restoring force to the normal-fluid motion. We can expect some new effects at elevated pressures in comparison with the case of Vycor.

We have observed longitudinal ultrasound of liquid ^{4}He in various aerogels at saturated vapor pressure [12,13]. The sound velocity of aerogel can be varied by porosity and that of liquid by pressure. In the present study, sound measurement at high pressure has been done for 94.0% aerogel and superfluid transition was observed in over-pressure regime. The solidification pressure has been measured, too.

2. Experimental results and discussion

The sound cell is described in [12,13]. The ultrasonic measurements were made using a standard pulse transmission and a phase sensitive detection technique.

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